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Agricultural Research

Biocontrol's First Skirmisher

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Biological Pest Control
A Winning Strategy

Killing plant pests with chemicals, tillage, or by burning fields after harvest usually yields spectacular results relatively quickly.

Biological controls—such as beneficial insects and genes—on the other hand, tend to be slower and less visible but more compatible with today's goals: a cleaner environment and less dependence on agricultural chemicals.

Perhaps the oldest form of biological control is crop rotation. Farmers who use this simple yet effective technique allow the naturally occurring, helpful organisms in soil to work for them against one or more crop enemies. For example, by not growing wheat in the same field more than every second or third year, root parasites are forced into a lengthy dormancy. This gives beneficial parasites and predators more time to battle harmful parasites and sanitize the soil.

Another time-honored method of biological control involves introducing natural organisms that attack or inhibit a particular pest.

The first U.S. example of this type of control took place 100 years ago. The vedalia beetle, an Australian ladybug, was imported into California in 1889; to this day, it controls the cottonycushion scale insect on citrus. Growers are now able to protect everything from apples to zucchini from about 50 insect pests and 8 or 10 weeds by using one or more natural enemies, usually imported from the pest's homeland.

The advent of biotechnology tools promises to broaden the scope of this method by modifying or genetically altering natural organisms to enhance their usefulness.

Three biocontrol strategies are available to today's growers. The first strategy—which includes crop rotation and the release of natural enemies—is to regulate the pest population. With most weeds, insect pests, and nematodes, this may be the only acceptable or practical strategy.

In the case of the screwworm fly, the insect was used against itself. Mass releases of sterile male screwworm flies ensured barren matings and eradication from the United States of this major killer of livestock and wildlife. It also earned national and international honors for Edward F. Knipling, the ARS scientist who developed the technique.

The second strategy is to set up a system of plant defense, such as beneficial microorganisms, as a living barrier and deterrent to infection or pest attack.

Researchers have shown, for example, that crown gall caused by *Agrobacterium tumefaciens* can be controlled in ornamental plants and fruit trees by dipping the roots of young plants into a suspension of cells of the related, but harmless strain K_{84} of *A. radiobacter*. Strain K_{84} is thought to saturate the potential sites for infection on the roots as well as produce a substance that inhibits the harmful bacteria.

The third strategy is to use biotechnological tools to manipulate or create self-defense systems within the plant. As an example, genes produced by a strain of the insect pathogen *B. thuringiensis* have been engineered into tomato plants. Plants protected with these genes resist attack by hornworms, a major pest of tomatoes.

Like human or animal vaccination, we can now use "disarmed" strains of viruses (or genes from the virus) that will protect plants against harmful viruses. Recently, plants were engineered to produce the virus' outer covering, known as the coat protein. When the virus tries to enter such plants, the coat protein produced by these plants interferes with the ability of the virus to make its own coat. Plants engineered in this way are remarkably resistant.

Science is now revealing that some genes engineered for disease resistance literally turn on in plants in response to attempted infection by pathogens and shut off in their absence.

The opportunities for biological control are nearly unlimited. We can expect greater use of disarmed pathogens or their genes as biocontrol agents and of genetically engineered insect viruses designed to target specific insect pests. Other expectations include use of beneficial bacteria and fungi designed to live intimately with plants while arresting disease or pest activity and crop plants engineered to produce their own antibiotics for defense against pests and diseases.

Advancing America's biocontrol technology naturally and safely is an awesome task. We need to blend the highly sophisticated and exciting new biotechnology—unheard of 20 years ago—with the more traditional, proven approaches to biological control. The stakes are high; the rewards, enormous.

R. James Cook
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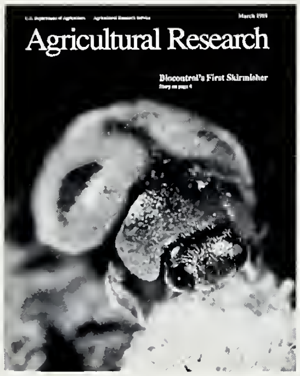
Agricultural Research



Cover: Imported from Australia for its biological control possibilities, the vedalia beetle immediately began eating its way through a troublesome population of citrus scale insects in California. Photo by Jack Kelly Clark. (89BW0184)

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DEPARTMENTS

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Biological Control
Turns 100 This Year

Hall of Heroes

From top: A sevenspotted lady beetle captures a pea aphid, one of its favorite dinners. (0678X780-17) A Mexican bean beetle larva becomes a meal for the spined soldier bug. (0484W406-3) The parasitic wasp *Microplitis croceipes* lays her eggs in a tobacco budworm. (88BW0705-14)
Facing page: *Lemophagus curtus* injects her eggs into the larva of a cereal leaf beetle. (PN-6861) A tiny flea beetle on leafy spurge, a costly weed of western rangeland. (PN-7241) The South American flea beetle, *Agasicles hydrophilia*, eats alligator-weed, the scourge of many Southern waterways. (0474X552-1A)

A scientific strategy was born in a citrus grove in 1889, in what is now the city of Los Angeles, California.

Citrus trees were overrun with an introduced pest called cottonycushion scale, which threatened to destroy the fledgling citrus industry in California. Hoping to stop the insect, scientists released 129 imported Australian vedalia beetles.

The beetles, which had been collected by a U.S. Department of Agriculture explorer at a cost of about $2,000, immediately began to reproduce and soon spread throughout citrus-growing areas. By the end of the project's first year, the beetles had dramatically reduced the scale population. Never again would cottonycushion scale be a serious problem for citrus growers.

The technique of releasing an imported organism that establishes itself and spreads to permanently control a pest is today known as the classical biological control concept. With successful classical biocontrol, once a predator is released, no further costs are required to keep the pest under control.

After the Vedalia Beetle

According to the Agricultural Research Service's Jack Coulson, an entomologist at the Beneficial Insects Laboratory at Beltsville, Maryland, the concept of importing beneficial predator insects and parasites dominated pest control strategies at USDA throughout the quarter century after the vedalia beetle.

Among the pests whose populations were, to various degrees, curtailed in the very early years of biocontrol: Gypsy, Oriental, satin, and browntail moths in New England; sugarcane borer in Florida; the alfalfa weevil in the West; the European corn borer and Japanese beetle in the East; and the European earwig in the Northwest.

And, Coulson says, although most of the imported predators were not as successful as the vedalia beetle, "the projects were central to scientists' understanding the principles of biological control."

During these early projects, scientists began to realize that it was not enough to simply import and release a biological control once and then forget it. Many of the organisms needed to have their populations renewed from time to time.

This augmenting of the organism's numbers usually involves mass-rearing.

Scientists have augmented native U.S. enemies of boll weevil, horseflies, aphids, and the Oriental fruit moth. The Oriental fruit moth project, in which 500 braconid wasps per acre each year were released, achieved a 50-percent injury reduction in peaches. Officials of Colorado and other states still release the wasps periodically to control the fruit moths.

Scientists also started using insect diseases to control pests, although not all of these efforts produced good results.

For example, when scientists found native chinch bugs that had a fungal disease, they devised a disease augmentation program in which they released infected bugs to curb this pest of grain and grasses.

To their disappointment, they later discovered that many bugs from different parts of the country were already infected with the same fungus. Their efforts hadn't added enough to prove an effective control method.

Some insect diseases seem more promising. A grasshopper disease called *Entomophthora gylli* was imported from South Africa and grown in labs. It was then released as cultured spores. Scientists at ARS' Plant Protection Research Lab in Ithaca, New York, are still studying the fungus as a possible biocontrol for grasshoppers.

Other pests that scientists tried to curb with fungus are the browntail moth, citrus whitefly, and European corn borer. Native diseases specific to the moth and whitefly were used, while the fungus for the corn borer was imported from China. Although they didn't fully succeed as biocontrols, they did help mark another step of growth for the technology.

In 1912, attention turned to a whole new aspect of biocontrol—conservation. Scientists began to devise ways to

preserve or augment pests' natural enemies that dwell in a crop field as part of the ecosystem.

One early conservation project targeted the boll weevil in cotton. The technique called for farmers to alternate cotton rows with rows of a plant that attracted weevils that have parasites that attack boll weevils. The "good guy" weevils weren't interested in cotton; only in the alternative plants. Coulson says, "It's a project that worked fairly well but was never followed through. It probably should have been."

Biocontrol Makes Good

In the 1920's and early 1930's, USDA and other scientists began studying soil organisms for control of plant disease and nematodes. But for years, the research seemed to offer little payoff; scientists got such minimal control that this kind of research essentially stopped.

It wasn't until 1955 that scientists began to take a second look at controlling soil diseases with soil organisms. One target was a *Rhizoctonia* fungus that attacks the roots of 200 economically important crops, including wheat and barley. Those first studies have led to the development of environmentally safe delivery systems for, and possible eventual marketing of, two bacteria that control the fungus.

In the 1930's and 1940's, USDA had a few noteworthy biocontrol accomplishments: Complete control of the Comstock mealybug in the East and of the newly introduced citrus blackfly in Mexico, substantial control of the larch casebearer in the Northeast, and partial suppression of the San Jose scale, elm leaf beetle, fig scale, and asparagus beetle in the West.

And the first commercially marketed microbial pesticide came out of this period of biocontrol's development: Milky spore disease to control Japanese beetle larvae. ARS scientists developed ways to produce, store, and distribute spores of *Bacillus popilliae,* which causes the disease.

Although they distributed it in 14 states and Washington, D.C., they found the disease did not spread quickly enough to keep up with the rapidly spreading Japanese beetles and become an effective classical biocontrol. To help *B. popilliae* catch up, commercial firms began selling milky spore as a commercial product, Coulson says. Currently, homeowners can purchase it for their yards, or whole communities can pitch in and pay a firm to treat an entire area.

Coulson says, "We expect the Japanese beetle will keep spreading. Eventually, it could infest all of the United States." It was first found in the Northeast and is moving west, as well as south into the Carolinas. "We're fortunate that we have this potent disease organism to control the pest," which, in its different growth stages, can destroy grass, roses, and even some crops.

Another bacillus—named *B. thuringiensis*—was also being studied as a biocontrol for insects during the thirties and forties. Later, it would become a top microbial pesticide.

Weeds didn't become biocontrol targets until 1944, when permission was finally granted for the introduction into the United States of weed-eating insects. The first weed victim, St. Johnswort, was knocked back by two beetles that Australian scientists had found to be good controls. Today, St. Johnswort infests less than 1 percent of the area it used to occupy in California.

DDT Enters the Scene

Despite biocontrol's successes, in the 1940's chemical insecticides distracted scientific attention from all aspects of biocontrol, Coulson says. Starting with the discovery of dichlorodiphenyltrichloroethane, or DDT, in 1939, chemists found they could fairly easily formulate new hydrocarbon toxins to kill pests. It seemed that no one foresaw any problems with these toxic substances, which were as yet too new to be assessed for environmental impact.

By 1955, the trend began to swing back. But this time, scientists weren't turning to biocontrol simply because

they had no alternatives, as had been the case in the late 1800's. This time, biocontrol methods were sought to replace methods that risked damaging the environment.

In 1962, the publication of "Silent Spring," Rachel Carson's landmark book about the environmental impact of various industrial and agricultural chemicals, especially DDT, reinvigorated concern in the scientific community and the public about the condition of the nation's water, soil, and air, as well as about pesticide residues appearing in foods.

Another concern centered on the diminishing effectiveness of chemical pesticides: scientists found that with each generation, insects became able to tolerate larger and larger amounts of the chemicals.

The message was clear. Although finding new toxicants might not be as complex as importing and using natural control methods, the benefits of chemical controls might prove to be merely temporary. Biocontrols, on the other hand, offered long-lasting control that organisms didn't become resistant to.

Finally, scientists began to realize that chemicals tended to disrupt, rather than conserve, field ecosystems. When sprayed in a field, the toxins often killed whatever organisms might be providing natural control in a field.

1950's—Classical Biocontrol Rebounds

In the fifties, more conservation research was done. Although farmers never used the technology, scientists found that when they constructed little wooden shelters for predaceous wasps, they achieved better control of the tobacco hornworm.

And scientists and farmers alike started realizing that by timing insecticide applications just right—or by cutting back on the number of them—the natural enemies already out in the field would have a fighting chance to provide some pest control free of charge. There is little recorded on how much money or what crops conservation biocontrol has saved, Coulson says.

But since the 1950's, classical biocontrol has brought American agriculture control of serious introduced pests, including the cereal leaf beetle, the alfalfa weevil, the alfalfa blotch leafminer, and the pea aphid in alfalfa.

The estimated savings on just these four pests due to classical biological control: Over $112 million *every year,* according to scientists at the ARS Beneficial Insects Research Laboratory at Newark, Delaware.

"That's a good payoff when you compare it to the $20 million ARS spends annually on all aspects of biological control research," Coulson says.

Among successes of biocontrol of weeds is alligatorweed. Originally from South America, it was ARS's first aquatic biocontrol triumph. About 20 years ago, USDA scientists went to Argentina to find insects that might eat the weed. The result: Three that were hungry for nothing but alligatorweed, released between 1964 and 1971.

A Rogue's Gallery

A foursome of pernicious pests, each the target of biocontrol efforts. From top left, gypsy moth, *Porthetria dispar.* (0787X772-24) Below, the recently-imported, not to mention costly, Russian wheat aphid, *Diuraphis noxia.* (89BW0110) Colorado potato beetles, *Leptinotarsa decemlineata.* (0687X533-8); and grasshopper, *Melanoplus bivattus* . (0779X981-18A)

One, the alligatorweed flea beetle, has practically eliminated the weed in Florida. Another, a moth, helped its beetle buddy bring alligatorweed under control in the Mississippi Valley, and the third, a thrips, has done its small part in controlling alligatorweed along the banks of lakes and rivers.

The past several decades have also brought disease organisms into commercial labs and, from there, into the field. For example, in 1987 Evans BioControl, of Broomfield, Colorado, and Bozeman Bio Tech in Bozeman, Montana, began marketing an ARS-studied grasshopper disease.

In about 25 years of research, J.E. Henry (now retired) and colleagues at the Rangeland Insect Lab in Bozeman, showed that the protozoan *Nosema locustae* kills 50-60 percent of grasshoppers in 3 to 4 weeks. "The parasite depletes the grasshopper's fat stores and leaves it without energy," Henry says. While grasshoppers are dying, they are, of course, less mobile and eat less.

Henry and colleagues also developed ways to produce and store the protozoan.

The two firms picked up the technology and now sell the biocontrol on a bran bait to homeowners and ranchers through regional agents and on contract to government agencies. Those agencies are using it on a wide scale in the West, where grasshoppers devastate grass and crops. Total U.S. cost of grasshopper damage to ranchers, farmers, government agencies, and homeowners? A cool $400 million a year, Henry estimates.

Among other commercial products that have resulted, at least in part, from years of extensive ARS research are Thuricide and Dipel, trade names for an organism with the same scientific name, *Bacillus thuringiensis.* The strain of Bt currently found in Thuricide and Dipel is HD1—for Howard Dulmage's first strain. Dulmage is an ARS scientist stationed at Weslaco, Texas.

In the 1970's, the Biological Control Documentation Center was developed at Beltsville, Maryland. The Center holds files of USDA and state projects dating back to 1934. Those files include

Bio-Strategists and Tacticians

Clockwise from right: Geneticist Phyllis Martin sprays a new Bt solution on tomato plants to determine its toxicity to the Colorado potato beetle. (0787X770-21) Entomologist John Tanner examines gypsy moth egg masses in cold storage. (0387X226-30A) Entomologist Jack Coulson uses resources in the Biocontrol Documentation Center located in Beltsville, Maryland. (89BW0178-4) Entomologist James Svoboda compares a stunted tobacco hornworm to a normal one. (0684X852-16)

literature, unpublished records and data, and correspondence on natural enemy introductions.

Coulson, who maintains the Center, says one of its missions is to create computerized data bases that will include all available information about both domestic and foreign biocontrol agents. Scientists will be able to access the data bases for information on enemies—native, introduced, and foreign—of all kinds of pests, so that research projects can be conducted with full knowledge of known natural enemies and of past attempts at using them.

Where Biocontrol Research Stands Now

According to Richard Soper, national program leader for biocontrol, ARS' biocontrol scientists work on almost every imaginable economically important pest.

There are plenty of plans to control pests in ways that don't hurt the environment or nontarget organisms. Crop resistance, sterile insect release, crop rotation to cut down on need for chemicals, or even spraying insects with copies of natural hormones that prevent their development are all alternatives to chemical control. Currently, a controversy rages over whether these control methods should be considered within a new, broader definition of biological control.

A hundred years ago in a citrus grove, science brought forth biocontrol with its first pest control breakthrough in the United States. Today, biocontrol has matured into a respected agricultural discipline.—By Jessica Morrison, ARS.

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The Conqueror of Klamathweed

It's not every insect that gets a monument erected in its honor. But then, the Klamathweed beetle is not your average six-legged critter—at least not in the eyes of ranchers around Eureka, California.

Those ranchers remember how, on February 12, 1946, the stout, shiny little immigrant from Australia was turned loose to begin gobbling up a worrisome western weed.

Aggressively spreading across rangeland from Northern California to southern British Columbia, the poisonous Klamathweed (also St. Johnswort, goatweed) had already taken over about 2 million acres.

Within 10 years, a thriving beetle population reduced the yellow-flowered, 1-to-3 foot tall weed by a whopping 99 percent. Estimated savings to ranchers—$23 million per year.

University of California and USDA scientists imported the Klamathweed beetle in what was apparently one of the first attempts in the continental United States to control a weed with a plant-feeding insect.

Friendly Flies May Stop Starthistle

Charley Turner's first and most painful encounter with yellow starthistle was back in 1972, when he was vacationing in California.

No one warned him about the nasty weed's needle-sharp spines or told him that you never take a shortcut through a starthistle-infested field if you're wearing hiking shorts.

Last summer, Turner—now a botanist with the ARS Plant Protection unit, Albany, California—got his revenge.

From Greece, where starthistle is a native plant, Turner imported a powerful natural enemy of the weed—a peacock fly known as *Chaetorellia australis.* With the OK of federal, state, and county agencies, he turned about 200 of the flies loose in a field full of starthistle, about 20 miles from his Albany laboratory.

The insect has a proven ability to seek out and destroy starthistle's developing seed. That can spell doom for the plant, because seeds are the weed's only way to reproduce itself.

Experiments conducted by Rouhollah Sobhian at the ARS Biological Control of Weeds Station in Thessaloniki, Greece, showed that a single peacock fly larva can tunnel into and eat more than 90 percent of the developing seeds in a starthistle flowerhead.

Other tests by Turner, Sobhian, and Stephen L. Clement (now in ARS' Plant Germplasm Introduction and Testing research at Pullman, Washington) and Donald M. Maddox (now retired from Albany), proved that the fly would be safe to bring to America.

Hopefully, the peacock flies will adapt to their new California home and produce offspring that will become a thorn in starthistle's side.

Starthistle not only jabs hikers, but also poisons horses and crowds out useful plants that livestock could eat. Horses that eat too much of the weed for too long can die from starvation—the result of a chewing disorder *(nigropallidal encephalomalacia)* caused by the plant.

In spring and summer, the weed grows 1 to 3 feet high, with bright yellow flowers the size of a native Europe and western Asia. "In Greece, you might find an occasional patch of starthistle plants here and there along the side of a road or in a field," he says. "That's nothing like the problem here in California, where there are whole fields of it."

Turner hopes to release more of the flies, provided by Sobhian's laboratory, in Idaho, Washington, and Oregon in the summer of 1989.

The peacock fly is only the third insect to be approved for starthistle control in the United States. The first insect, another species of peacock fly, was introduced in 1969, but failed to adapt to the California plants. The second was a flowerhead weevil, *Bangasternus orientalis.* ARS researchers in California and in Greece coordinated its introduction into the United States. Now, small colonies of the insect are living in California, Idaho, Oregon, and Washington. It's still "too early to know what impact the weevil might have," Turner says.

The weevil and the peacock fly apparently don't compete with each other, so they should be able to cooperate to stop starthistle's spread.—By **Marcia Wood**, ARS.

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Chaetorellia australis, a peacock fly native to Europe and western Asia, has been released in the United States to help control starthistle. (89BW0144)

Starthistle is an annual weed occurring mostly in western rangelands, but is scattered throughout the United States. Growing 1 to 3 feet tall, with inconspicuous yellow flowers, its sharp spines can injure livestock when they eat it.

Immigrant Pests
Locating Enemies Abroad

While the United States is known as the "melting pot," you can't discount Italy.

You see, when Rome became a center of trade at the beginning of the Roman Empire, it also evolved into a melting pot of weeds.

As traders from other countries came to Rome, they not only brought goods for trade but, by accident, weeds from their native lands. The area virtually has become a who's who of weeds.

One weed to migrate into Italy is the musk thistle, whose origins have been traced to eastern Russia, says Gaetano Campobasso, an ARS entomologist. Campobasso has been working on research to control growth of the musk thistle since 1974, but research on the musk thistle actually began in 1956 when the ARS Rome lab was established.

Because the area has such a large variety of weeds, Rome was the ideal place for research into control of weeds, says Lloyd Knutson, director of the Biological Control of Weeds Lab in Rome.

Since research on the musk thistle began, ARS scientists have identified four insects that can actually curb its growth. Two of those insects—the *Rhinocyllus conilcus* and *Trichosirocallus horridus*—have been given the green light to combat musk thistle in the western United States. Petitions to release two others, the *Cheilosia corydon* and *Psylliodes chalcomera,* will be filed, says Campobasso.

The musk thistle is just one example of weed control research at the Rome lab. The lab is similar to ARS labs in France, Argentina, and Korea that search for parasites, predators, and disease organisms that might manage pests in the United States.

French Apple Orchards

At the European Parasite Laboratory in Behoust, France, just west of Paris, a moth whose larvae eat apple tree leaves is the focus of one typical biocontrol project.

"Although the ermine moth only occurs in Washington State and Canada and is not a serious pest yet, apple producers are afraid it could develop larger populations and spread to other states," says Ray Moore, who heads up the lab.

The moth builds its tentlike nests in apple trees, and larvae emerge to feed on leaves, weakening the tree. "A tree can actually handle one or two tent nests, but larger numbers would decrease fruit yield and quality."

The top candidate for controlling the ermine moth right now is a parasitic wasp called *Ageniaspis fuscicollis.* When lab entomologist Kim Chen reviewed the literature, he found that this wasp parasitizes as much as 50 percent of the egg masses after 3 years.

In addition, he checked the literature to make sure the wasp would not attack lady bugs, honey bees, or other beneficial insects. "The literature indicated

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Entomologist Gaetano Campobasso collecting flea beetles, *Psylliodes chalcomera,* from musk thistle plants near the ARS Rome, Italy, lab. (88BW1057-13)

TIM McCABE

Before being released in the United States, biocontrol insects, such as the flea beetles entomologist Gaetano Campobasso is watching, are caged with as many as 65 different crop and ornamental plants to make sure they eat only the target weed. (88BW1053-27)

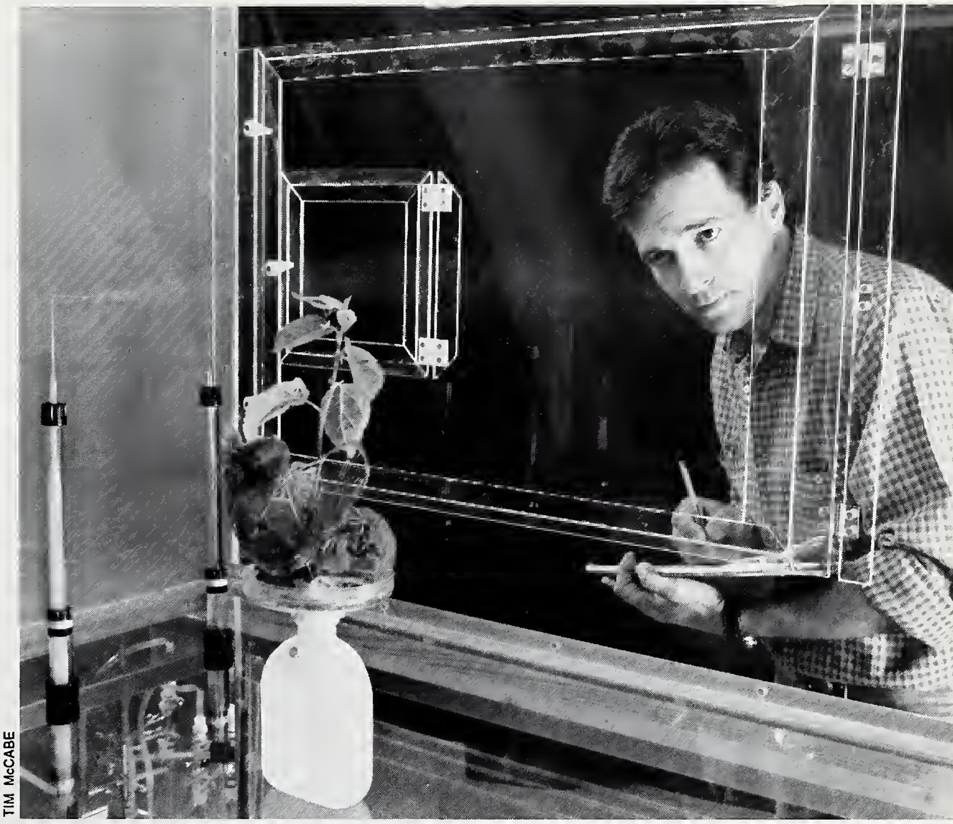
ermine moths are the only organisms this wasp will lay its eggs in," Chen says.

To gather these tiny wasps, Chen, along with entomologists Keith Hopper and Franck Herard, get into their station wagon and look for abandoned apple orchards in southern France. "Abandoned orchards are best because you have trees that haven't recently been sprayed, which could kill or weaken the parasites," Hopper says.

When they find apple ermine moth tents, they saw off those branches and put them into a container.

Back at the lab, the scientists open up the tents and separate healthy ermine larvae from ones that have developing baby wasps in them. Called mummies because developing wasps have eaten their insides out, these victimized, dead ermine worms still harbor wasp larvae.

A female wasp lays only one egg in an ermine larva, but 60 to 120 wasps emerge from the larva. This phenomenon—one egg dividing into many—is called polyembryony.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Franck Herard watches a wisp of smoke in a laboratory wind tunnel that helps him track the movement of insect pheromones in the air. He is studying *Ageniaspis fuscicollis,* a wasp that parasitizes the eggs of apple ermine moths. (88BW1045-7)

Looking for Hyperparasites

At the lab, the scientists must check *A. fuscicollis* for parasites of their own—called hyperparasites. "This is important," Hopper says, "because if a parasite has its own natural enemies, it may not be able to establish itself well enough to control the ermine moth."

Next, they cool the insects to 60°F so that wasp development slows down. That way, scientists can later time their emergence with their ermine moth victims back in the United States.

The scientists package over 3,000 of the mummies in sealed foam containers with ice packs to keep them fresh and send them via air parcel service to the ARS Beneficial Insects Laboratory in Newark, Delaware. There, they are quarantined and studied.

Each time they send a package of wasps to the United States, the scientists in France alert Lawrence R. Ertle, who heads up the quarantine section at the lab, that the mummies are coming. He makes sure to greet the fragile cargo at Philadelphia International Airport so it doesn't sit too long.

"Most parasites only last about a day or two in the environment of the sealed package," he says. "The flight itself can take 24 hours, and then the package has to go through customs the next day, so it's critical that I be there to meet it."

Once safely back inside Newark's quarantine facility, Ertle lets the wasps come out of the mummies and quarantines them for a few weeks to check them for hyperparasites or other insects that might have hitched a ride in the package. Sometimes, imported insects have to be destroyed at this point, he says, because they may bring fellow travellers that could threaten the United States with a new pest.

Next, he sends samples of the wasps to ARS' Systematic Entomology Lab at Beltsville, Maryland, for positive identification.

Then Ertle sends wasps to Jim Krysan and Tom Unruh at the Agricultural Research Service Lab in Yakima, Washington. The total he's sent to them: 33,500. Krysan and Unruh released the wasps last summer. It will take a couple of years for the verdict on whether or not they'll provide good control or even establish themselves.

But if they do, they could be a biocontrol that works against other ermine moths—including ones that are pests of cherry and plum trees in Europe and Asia.

Other targeted pests at the French lab: The Russian wheat aphid, lygus bugs, house and stable flies, gypsy moths, and potato leafhoppers. Besides looking for parasites and predators, the lab has a pathologist searching for fungal pathogens of these pests.

According to Knutson, the quarantine research process for biocontrols of weeds can take years, instead of the

weeks or months for biocontrol agents of insects.

"With any weed feeder, you want to be sure it won't turn to crops or U.S. endangered species of plants if its host becomes scarce," Knutson says. "We even starve them and offer them only wheat, for example, and if they still won't attack it, we know we're safe."

As many as 65 plant species are tested with weed-eating insects or mites. In all, about 40 species of insects and mites attacking 17 species of weeds have been studied.

At the Rome lab, scientists are now not only studying musk thistle, but also leafy spurge, knapweed, and yellow starthistle and have studied many other weeds in the past.

Seven biological agents that control weeds have been released in the United States and are currently being used. An additional 12 for weeds are expected to be released by 1991.

At the Buenos Aires lab, waterweeds, flies, southeastern pasture and crop weeds, and fire ants are being studied. For waterweed work, Hugo A. Cordo and colleagues work with the Aquatic Weed Control Research Laboratory in Fort Lauderdale, Florida. Fly and fire ant biocontrols are sent through the Newark quarantine facility, while land weed biocontrols go through the Bozeman lab.

At the Asian Parasite Laboratory in Seoul, Korea, scientists are working on the Mexican bean beetle, pear psylla, and the Japanese beetle, as well as forest pests like gypsy moth, red pine scale, and hemlock scale. Enemies coming from there go through the Newark lab.

The China Connection

ARS and the Peoples' Republic of China are opening a joint lab in Beijing as a research facility and quarantine for biocontrols of both American and Chinese insect pests and weeds. Called the Sino-American Biological Control Collaborative Laboratory, the facility is housed at the Chinese Academy of Agricultural Sciences. Under a 5-year

TIM McCABE

ARS entomologist Keith Hopper (left) and French entomologist Franck Herard collect apple ermine moth larvae in Normandy. (88BW1043-3)

agreement with the Academy, three ARS scientists will go to the lab this spring. They'll do research there for 6 months each year and then return to the United States and to the Rome lab to continue their current research. The U.S. pests to

be studied are leafy spurge, a noxious weed that infests nearly 3 million acres of western rangeland and costs ranchers $20 to $30 million a year; two water-weeds, hydrilla and watermilfoil; and the Russian wheat aphid, which has spread rapidly throughout the western United States and southwestern Canada since its introduction in 1986.

Of concern to the Chinese are croftonweed, so toxic to horses that they can't be kept on certain land; scale insects; and apple leaf mites.

Next year, the Academy will send Chinese scientists to ARS labs, possibly in Fort Lauderdale and Buenos Aires.

Richard S. Soper, ARS national program leader for biological control research, points out that until now, ARS has not found it easy to explore much of Europe and Asia.

"The new lab takes care of some of the area we've missed, and we're hoping we can develop similar arrangements with the Soviets."

Whether in China, Italy, or perhaps one day the Soviet Union, ARS scientists will continue recruiting natural enemies to fight agriculture's pests.—By **Jessica Morrison,** ARS. **Bruce Kinzel,** ARS, contributed to this article.

Richard S. Soper is the National Program Leader for Biological Control, Bldg. 005, Beltsville Agricultural Research Center-West, Beltsville, MD 20705 (301) 344-3930.

Biocontrol's 100th birthday will be celebrated at two symposiums co-sponsored by USDA, the University of California, the Entomological Society of America, and others.

The first, International Vedalia Symposium on Biological Control: A Century of Success *will be held March 27-30, 1989, in Riverside, California. For more information, Contact R.F. Luck, University of California at Riverside. His phone number is (714) 787-5713.*

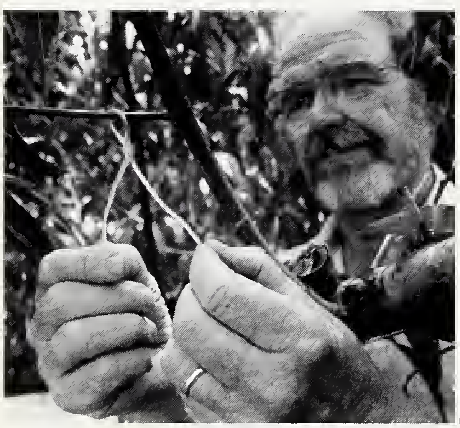
The second, International Symposium on Biological Control Implementation *will be held in McAllen, Texas, April 4-6, 1989. For more information, call G.L. Cunningham, USDA-APHIS (301) 436-8038.* ♦

Benchmarks in Biological Control

1889	Release of Australian vedalia beetles to control cottonycushion scale, which threatened citrus industry in California.
1929	Discovery that native *Macrocentrus ancylivorus* wasp attacks newly introduced Oriental fruit moth. Wasp population is augmented yearly to control the moth.
1939	Distribution of *Bacillus popilliae,* that which became the first commercial microbial pesticide; it attacks Japanese beetles.
1944	Importation of biocontrol beetles from Australia to control the range weed St. Johnswort; two were found to be effective.
1957	Importation of parasites against alfalfa weevils, achieving increasing control by 1980. Estimated savings $49 million annually.
1959	Release of a parasite against the grass and forage pest Rhodesgrass mealybug; mealybug eliminated as a pest by 1970.
1964	Introduction of three insects—a beetle, a moth, and a thrips—that eat alligatorweed. It was controled in the Southeast by 1978.
1966	Parasites found in Europe begin to control the cereal leaf beetle, a pest of grain crops. This was the first time that an *annual* crop was freed from a pest using imported biocontrols.
1966	Isolation of the strain of *Bacillus thuringiensis* that would become the top-selling microbial pesticide for use against grasshoppers.
1970	Isolation of *Colletotrichum gloeosporiodes,* which became the first commercially available microbial weed killer; it controls northern jointvetch in rice and soybeans.
1974	Release of the first European parasites against a new pest, the alfalfa blotch leafminer; control by 1980.
1983	Beginning of control of scale insects on a popular ornamental—Euonymus—with a red spotted black ladybug and a black beetle from South Korea.

Blunting the Peachtree Borer

Technician John Blythe examines wound on a peach tree caused by the lesser peachtree borer. (88BW2106-33)



Entomologist Wendell Snow demonstrates a possible solution: plastic twist tie dispensers impregnated with pheromones. (88BW2110-15)

Peach-Growing Areas Subject to Damage From Borers

	Acres
Alabama	7,000
Arkansas	1,900
Georgia	19,000
Florida	5,000
Louisiana	2,000
Michigan	7,300
Mississippi	2,000
New Jersey	13,000
New York	2,100
North Carolina	3,500
Ohio	1,000
Pennsylvania	7,600
South Carolina	35,000
Virginia	2,500
West Virginia	3,200

This spring if you notice a gummy, brownish substance oozing from the trunk or limbs of your peach tree, it's probably the result of a lesser peachtree borer larva having a feast.

The brownish stuff is a mixture of gum from the wounded tree and insect excrement. While this insect is feeding on the soft, inner tissues of tree limbs, larvae of a close relative, the peachtree borer can be gnawing away at the base and roots. No part of the tree is safe from the peachtree borer.

"Together, these insects cost Georgia peach growers about $1.6 million a year in crop losses and control costs," says J. Wendell Snow. Nationwide, the problem costs about $20 million annually."

The lesser peachtree borer is found in Canada and the eastern part of the United States while the peachtree borer inhabits most of the United States. Oddly, damage is severe only in areas east of the Mississippi River. Almost every peach tree over 3 years old in this geographic area is infested by one or both species. California, the largest peach-producing state, does not have a major problem with either of them.

The peachtree borer, *Synanthedon exitiosa*, and the lesser peachtree borer, *S. pictipes*, are native American species that feed on other fruit trees such as almond and wild and cultivated cherry and plum, but peach has become the primary host.

"Peach growers have only two approved pesticides to control their number one insect problem," says Snow, director of ARS' Fruit and Tree Nut Research Laboratory in Byron, Georgia.

Spraying Lorsban once a season on tree trunks will control the peachtree borer, but two applications of Thiodan to lower branches and tree trunks are necessary to control the lesser borer.

"In applying these pesticides, timing and precision are critical," says Snow. "It's difficult to determine the perfect time to spray, and almost impossible to cover all affected areas on trees."

"Then too, there's the problem of possible pesticide residue on the fruit."

Good reasons, then, to look at new ways to stop the devastation caused by the borer larvae.

Snow and colleagues with ARS at the Gainesville, Florida, Insect Ecology Research Laboratory determined that the mating routine of the borers could be disrupted by filling the air around an infested tree with the female insects' pheromones. Disruption was greatest when the pheromones were dispersed from the tops of peach trees.

An early conclusion that the pheromones could be synthesized and used interchangeably to control both insects proved wrong. In 1984, Byron scientists discovered that each insect must be controlled by its own synthesized pheromone.

In a 5-year study of several peach orchards in central Georgia, Byron scientists achieved almost complete control of the insects by hanging a pheromone-containing dispenser in each tree.

"It works like this," says Snow. "The insects try to mate daily, from around 11 in the morning until about 2 in the afternoon. This goes on for about 2 weeks, the lifespan of the adult. Well, when the male futilely approaches the dispenser so many times, he becomes totally confused and exhausted."

Therefore, the synthesized pheromones (which are stronger than those produced by the insects) prevent mating, reducing populations of both pests to practically zero. Those female insects already in orchards remain barren, thereby breaking the egg/larva/adult cycle.

Snow says some damage will occur from mated migrating females from adjacent fields, but the pheromones will affect their progeny. In most cases, the damage will be insignificant.

Resembling a pipe cleaner or a trash bag twist tie, the dispenser, made of polyethylene plastic and twisted around a tree branch, continually wafts the pheromones through the air.

The lesser peachtree borer is active throughout the entire season from March through October, peaking in August. Peachtree borer activity peaks in August and September. Therefore, one dispenser in late March is needed for the lesser borer; then in early August, another dispenser is required to control the peachtree borer. (Leaving no harmful residue, pheromones can be used at any time.)

Manufactured by Biocontrol, Ltd., an Australian company with offices in Davis, California, the dispenser is being reviewed by the U.S. Environmental Protection Agency for commerical use. Approval is expected some time in 1989.

"We expect the pheromones to be cost-competitive with current control methods," says Snow. "Not only is this biological control a good example of technology transfer, but it is also more effective and efficient than pesticides."

Cooperators around the country are evaluating the effectiveness of the synthesized pheromones under different growing and weather conditions. Test sites include Clemson University, Clemson, South Carolina; Virginia Tech, Blacksburg, Virginia; Penn State, University Park and Biglerville, Pennsylvania; and Rutgers Research Center, Cream Ridge, New Jersey.—By **Doris Sanchez**, ARS.

J. Wendell Snow is at the USDA-ARS Southeastern Fruit and Tree Nut Research Laboratory, ARS-USDA, P.O. Box 87, Byron, GA 31008 (912) 956-5656. ♦

A goodly catch of lesser peachtree borers is inspected by technicians Kathy Scarborough and John Blythe as they check traps that have been baited with small amounts of pheromones. (88BW2110-3)

ROB FLYNN

Natural Sugar Cuts *Salmonella* in Broilers

A natural sugar is thought to have helped sustain the Israelites of Old Testament days during their 40 years in the wilderness. Now the same sugar, D-mannose, appears to offer a key to controlling *Salmonella typhimurium* infection in broilers.

Produced naturally by the *Fraxinus ornus* plant along the Mediterranean basin, D-mannose may have been an ingredient in the Israelites' "manna from heaven," described in the Bible.

". . . the total number of Salmonella bacteria in infected birds from the D-mannose group was 99 percent less than in those that got plain water."

John R. DeLoach, ARS biochemist, College Station, Texas

But a different type of literary reference caused Agricultural Research Service microbiologist Anthony B. Oyofo to turn to D-mannose as a solution to *Salmonella* infection in poultry.

"A number of scientific reports are suggesting that D-mannose may impair the ability of some bacteria to stick to intestinal tissue in rats and mice," says John R. DeLoach, a biochemist and Oyofo's research leader at ARS' Veterinary Toxicology Research unit in College Station, Texas.

"Adherence of the bacteria to the tissue—the bacteria's ability to stay around and cause problems—was blocked by the addition of sugar. And it was highly specific for this sugar."

Oyofo began his studies in February 1988 with test-tube screening of more than half a dozen natural sugars besides D-mannose.

Intestinal tissue from day-old broiler chicks was loaded with radioactive bacteria, then treated with a sugar. The intestines were then washed and scraped to get a count of the bacteria still clinging to the tissue.

CHRIS KEITH

Microbiologist Anthony Oyofo treats a laboratory chick to a dose of D-mannos, a natural sugar that tends to block the ability of *Salmonella typhimurium* to take hold in the bird's intestines. Oyofo discovered D-mannose's attributes while working in ARS' postdoctoral associates program at College Station, Texas. (88BW2239-31)

"D-mannose appeared to work best," Oyofo recalls. "The tests showed D-mannose inhibited adherence of the bacteria by 90 percent or more."

Encouraged by the outcome of the laboratory tests, Oyofo decided to test the sugar's impact on live broilers. One hundred and twenty chicks were given

an oral dose of 100 million *Salmonella typhimurium* bacteria on the third day of their life. Half of the chicks had been treated since birth with 2.5 percent D-mannose in their drinking water; this continued for another 7 days. The other 60 chicks did not receive D-mannose.

"Of the birds on plain water, 75 percent tested positive for *Salmonella typhimurium* infection at the end of 10 days," DeLoach says. "But only 25 percent of the D-mannose group was positive for *Salmonella.*

"Not only did we have fewer birds from the D-mannose group with *Salmonella,* but the total number of *Salmonella* bacteria in those infected birds from the D-mannose group was 99 percent less than in the infected birds that got plain water."

The scientists gave bacteria to another group of 120 broilers on the third day of the birds' life, gave half of them 10 days of D-mannose in drinking water, and checked them all for *Salmonella* infection at 50 days of age, the time when broilers might typically go to market.

"We only had one bird in the D-mannose group at day 50 with *Salmonella* colonizing in it," says Oyofo. "But in the group on plain water, we had six."

D-mannose, also known as seminose and carubinose, is available commercially in the United States. A sister compound, mannitol, has been used for many years as a stabilizer and preservative in pharmaceutical products.

"But for 5 and a half billion broilers annually, at 2.5 percent in the drinking water, we'd need 27,000 tons of D-mannose a year to supply the treatment," DeLoach says. "I don't think there's a big enough supply for that."

Fortunately, D-mannose can be produced from a variety of materials, including glucose, a component of table sugar, DeLoach says.

"Right now, if the poultry producer puts his birds on D-mannose for 10 days, it would cost him 50 cents a bird, which is too much," says DeLoach. "Our goal is to get the total cost down to less than 5 cents a bird."

What Is *Salmonella*

Even though food poisoning has been around about as long as we've had food, the reason food would "go bad" remained a mystery until early this century.

Today, we know what we were up against—toxic substances released by microorganisms. Many of the prime culprits in cases of food poisoning are bacteria in the genus *Salmonella.*

Researchers estimate that as many as 4 million Americans become ill each year after eating food contaminated with these rod-shaped bacteria. While healthy adults usually recover from the 1- to 5-day seige of fever, vomiting, and diarrhea, the disease is more dangerous to susceptible groups—the very young, the elderly, and those already sick. Annually, some 500 deaths are attributed to it.

Salmonella may take up residence in the digestive tracts of livestock and wild animals; some species may suffer disease symptoms, while others are virtually asymptomatic. Chickens which show few signs of *Salmonella* can nevertheless pass on the disease through their feces and occasionally within their eggs.

And despite renewed efforts at sanitation, the number of cases has been on the upswing in recent years. The Centers for Disease Control report a threefold increase between 1967 and 1986. This increase has occurred primarily in the Northeastern and Mid-Atlantic States.

That *Salmonella* is hard to subdue is not surprising; the genus of bacteria contains roughly 2,000 species that are widely distributed throughout the environment.

Although *Salmonella* bacteria grow readily on meat and foods made with meat or eggs, refrigeration inhibits their growth, and cooking destroys them, so these bacteria are normally kept in check. It is when food safety is overlooked that *Salmonella* bacteria multiply explosively.

DeLoach says he does not anticipate any reluctance by the U.S. Food and Drug Administration to approve use of D-mannose in poultry production.

"Mannose has no ill effects, and it is a naturally occurring sugar," he notes. "Besides, it'll be metabolized—burned up as an energy source in the bird, just like glucose is."

Future studies will focus in part on the possibility of adding D-mannose to poultry rations at the feed mills rather than in the drinking water.

"That would be easier for the producer," says DeLoach. "But we don't want to change the caloric value of the feed, so we'll have to take out some other energy source that's already in there.

"Broilers consume a lot of feed, so you may not need a level as high as 2.5 percent in the feed. We might be able to get away with only 1 percent. Or maybe we would just put the D-mannose in the starter feed for chicks and not the finishing feed, which would be consistent with normal practices in the broiler industry. We don't want to add a burden for the producer."—By Sandy Miller Hays, ARS.

John R. DeLoach and Anthony B. Oyofo are in USDA-ARS Veterinary Toxicology Research, P.O. Drawer GE, College Station, TX 77841 (409) 260-9484. ♦

Herbicide Spray Melts Leaf Wax

The delicate waxy designs on the surface of weed leaves could play a key role in killing those weeds at a fraction of the usual cost.

The story begins in 1983, when Chester G. McWhorter, a plant physiologist with the USDA Agricultural Research Service, was searching for a way to reduce the amount of water added to herbicide. In particular, he hoped to cut the typical 20 gallons of water per acre that were added to herbicides used to counter weeds like johnsongrass.

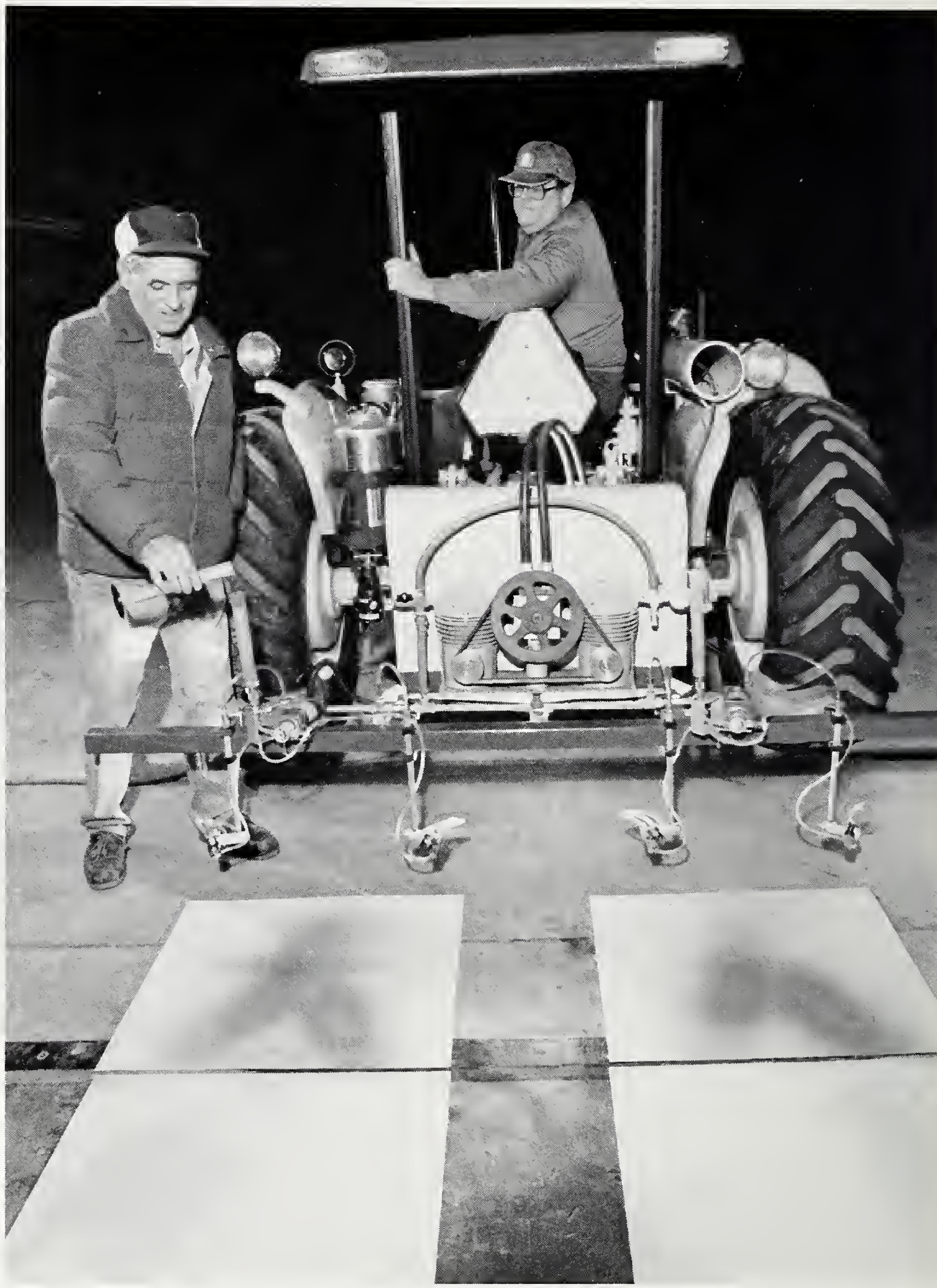
"We've had studies that showed 10 or 15 gallons worked just as well," says McWhorter, who works at ARS' Southern Weed Science Laboratory at Stoneville, Mississippi. "The ultimate question was, do we really need water in the system?"

The answer to that question appeared to be "no." McWhorter believed farmers could get good results by adding the herbicide directly to another important ingredient in the mix—an oil concentrate composed mostly of paraffinic oil.

Testing this theory in 1986, McWhorter and fellow researchers put fluorescent dye in various oil and water mixtures and volumes, sprayed them on weeds, waited 1 minute, and photographed the weeds—with startling results.

"Using water and soy oil at 20 gallons per acre, we got about 20 percent coverage," McWhorter recalls. "Water alone gave no spread. But when we made the application in a much smaller volume of paraffinic oil, we initially had droplets. Since they spread instantly, we had 100 percent coverage."

These findings also supported reports by English scientists in the 1950's that the rougher the leaf surface, the better the spread of oil, while the smoother the leaf surface, the better the spread of water.



BARRY FITZGERALD

Engineer Floyd Fulgham (standing) and technician Emile Daniel evaluate spray patterns and droplet size of oil-herbicide mixture from Fulgham's redesigned low-volume spray nozzles. (88BW2267-27)

When McWhorter checked leaves of 3- to 4-week-old johnsongrass, they were indeed rough—spiked with microscopic wax crystals.

"But as we enlarged our tests and went to johnsongrass of different ages, we didn't get consistent results," says McWhorter. "So we backed up and took another look at the wax we were dealing with on the surface of the plant."

The scientists discovered that when a johnsongrass leaf first emerges, the wax on its surface is smooth. Crystals start forming from the wax within 3 to 5 days, but as the plant ages, a smooth layer of wax grows over the crystals.

"That's why the older plant is more resistant to herbicides," says McWhorter. "There's that smooth barrier on top, plus there are air pockets between that top barrier and the leaf surface itself."

While the wax crystals are still on top, though, they pull the herbicide

REX N. PAUL

Although the wax on young johnsongrass leaves is smooth when the leaf first emerges, crystals begin forming from the wax 3 to 5 days (above 89BW0197). If the plant is sprayed with herbicide mixed with oil during this period, the crystals help pull the oil across the leaf surface. As the leaves age, another smooth layer of wax (below 89BW0198) covers these crystals, making it more difficult for oil to spread evenly.

across the surface of the weed leaf for complete coverage.

"The crystals spread the paraffinic oil, and then the oil melts the wax," McWhorter says. "When the wax dries again, the herbicide in the oil stays in the wax—it won't evaporate, and water won't wash it off."

But more than the help of the wax crystals was needed to get the best performance from the oil-herbicide mix.

"You can't take the fan nozzles used by farmers now and apply oil at low volumes," says McWhorter. "It comes out as a stream, not a flat-fan spray.

So Floyd E. Fulgham, an agricultural engineer with the Field Crops Mechanization unit at Stoneville, designed a nozzle called the Tee Mizer. It looks like an upside-down T, with air coming down from the top to help push the spray out. Farmers could easily use this with a compressor mounted on their tractors.

Armed with their new knowledge and equipment, McWhorter's team in 1988 took to the fields to try slashing herbicide rates to 1 or 2 pints of total liquid per acre.

"When you put herbicide out in this oil, the rates you need go down remarkably," McWhorter says. "With one herbicide we tried, the recommended rate would be about 0.125 pound per acre.

"Instead of 0.125 pound, we put out 0.025 pound up to 0.1 pound; we wanted sublethal rates to show different results. We got 90 percent control at one-fourth of the amount of herbicide you'd use in 20 gallons of water per acre."

Tests last year looked at half a dozen herbicides, the performance of ten different oils versus water, and varying air pressures in application.

The scientists also found that the crucial wax production pattern that helps spread the herbicide is frequently the same in other grasses as that seen in johnsongrass, McWhorter says.

"We looked at two dozen species, and found two that are somewhat different," he says. "Broadleaf signalgrass puts up a wax crystal, but it's a different chemistry of wax, and fall panicum is the same way. We don't know if that would pose a problem regarding herbicides.

"People always think at first that it would cost more to use oil instead of water to dispense herbicides. But farmers are already using crop oil in their herbicide mix. And actually our system is cheaper, because we're taking out the emulsifier you normally have to use because the herbicide isn't water-soluble.

"This probably won't work for all herbicides. But we think it will work for the aryloxyphenoxy propanoic acids, the herbicides commonly used for selected grass control."—By **Sandy Miller Hays**, ARS.

Chester G. McWhorter is in the USDA-ARS Southern Weed Science Laboratory, P.O. Box 350, Stoneville, MS 38776 (601) 686-2311.

Floyd E. Fulgham is in USDA-ARS Field Crops Mechanization Research, P.O. Box 36, Stoneville, MS 38776 (601) 686-2311. ♦

Coping With Crop Residues

Increasing profits—it's the name of the game for no-till and conservation tillage farmers. But that means increasing profits without wasting fuel, soil and other resources, and producing high yields. One winning strategy is to get crop plants off to a good start and to conserve fertilizer by modifying or improving farm equipment.

Since the early 1970's, scientists of the Agricultural Research Service and Iowa State University, Ames, jointly accumulated expertise that can help.

In research on no-till corn planters and conservation tillage machines, ARS agricultural engineer Donald C. Erbach has become a believer in coulters—rolling blades—to cut residue from previous crops. Coulters reduce the residue's potential to clog equipment, and on planters they loosen soil for covering seed. Coulters may roll freely at a speed approximating the tractor's groundspeed, or they may be powered by the tractor to run at faster speeds.

Erbach found that plants emerged faster from seeds dropped in the path of either free-rolling or powered coulters than from seeds planted without a coulter.

Powered coulters made the seeds go uniformly deeper where emergence-enhancing moisture was more plentiful. Getting plants growing quickly and uniformly may enhance corn yields, Erbach says. So can efficient fertilizer use.

James L. Baker, of the university's agricultural engineering department, came up with an idea for managing fertilizer placement and timing to make sure plants are well-fed and valuable nutrients are not washed by rains into lakes and streams.

(continued next page)

Instead of conventionally sidedressing corn—applying fertilizer in soil beside corn rows following knifelike blades—why not inject fertilizer through rolling spokes that poke inches apart into the soil beside the rows?

ARS agricultural engineer Thomas S. Colvin and soils technician Richard O. Hartwig teamed up with Baker and others to work out design details.

After research showed making the point injector fertilizer applicator was feasible, at least two Iowa farmers, Bill Cady of Colo and Lyle Overocker of Milford, developed their own. Cady, who was employed in the project in its early design stages, has refined the applicator and started a manufacturing firm, Cady Systems, Inc., that began marketing it in 1988. Overocker took a somewhat different approach in designing a rig for which a patent is pending.

A Different Approach

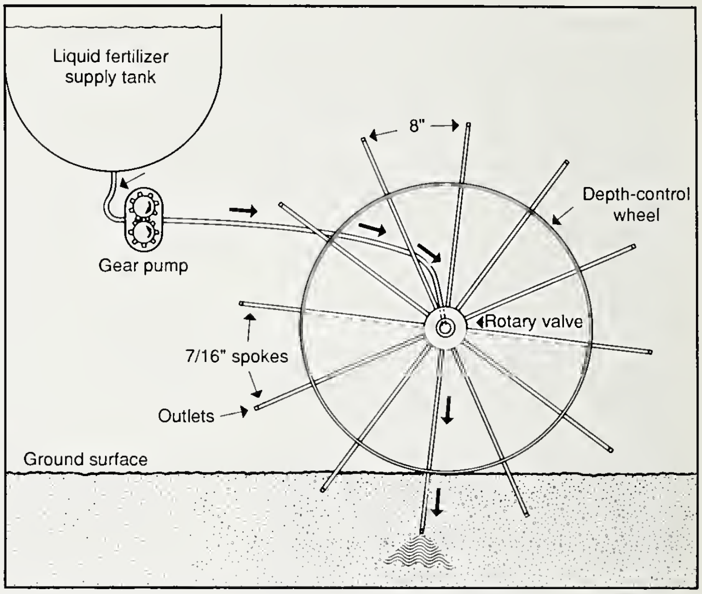
The Ames-type injector, mounted on a tractor tool bar, pumps liquid fertilizers such as ammonium nitrate through rolling spokes just when the spokes penetrate about 4 inches into soil. It wasn't designed to work with incompletely liquidized fertilizers, such as potash slurries with their high clay content, because grit might score a plastic inner bearing.

Used early in the season before the crop provides a canopy to protect soil from erosion, the spoke injector with its no-knife feature leaves residue from the previous crop nearly undisturbed to curb erosion, Colvin says. Used later in the season than would be practicable with a knife applicator, the injector doesn't slice corn roots away but feeds at a time when they can best use plant nutrients.

Point-injecting 156 pounds of nitrogen per acre resulted in increased average corn yields of about 7 bushels in the 1986-87 study that Baker and soil scientist Donald R. Timmons conducted. This average yield increase came with either single or split point injections in the row below the seed in contrast to applications knifed in deep bands about 5 inches from the row.

Splitting application of fertilizer throughout the growing season according to plant needs reduces the risk of nutrient losses through such processes as volatilization and denitrification as well as losses into lakes and streams, says Colvin.

But splitting applications to be in time with crop needs doesn't always mean higher yields.



Spoked injector for applying fertilizer through crop residues in conservation tillage farming. (Not to scale.)

In studies conducted by Baker and Timmons, corn fertilized in 1986 with split nitrogen injections yielded about 4 percent more than corn fertilized only at planting time. In 1987, corn with split injections yielded about 4 percent less. "We think soil moisture at application times may account for the difference," Timmons says.

Whether the applications are single or split, using the injectors could mean fuel savings. Colvin says a six-row model may require about a half-gallon less diesel fuel per acre than a knife-type applicator or about the same amount used for spraying.

Regardless of fuel used by tractors for either method, Colvin says, roughly two-thirds of a corn farmer's total energy cost is usually in the manufacturing of nitrogen fertilizer. One pound of nitrogen requires about the same amount of energy that's in one-fifth gallon of diesel fuel. Making sure nitrogen gets to corn roots instead of into lakes and streams could mean a big economic benefit, Colvin says.

Baker and ARS agricultural engineer John M. Laflen, formerly at Ames, using simulated rainfall tests, found that by point-injecting ammonium nitrate fertilizer, they could hold nitrogen runoff to levels no greater than those where no fertilizer had been applied. In contrast, they observed losses of about 5 percent from surface-applied ammonium nitrogen.

Farmers considering investment in spoked injectors should weigh all the costs and savings against expected increases in crop yields, Colvin says.—By **Ben Hardin**, ARS.

Scientists at Ames mentioned in this article can be reached at USDA-ARS Soil and Water Conservation Research, 213 Davidson Hall, Iowa State University, Ames, IA 50011 (515) 294-5724. John M. Laflen is now at the ARS National Soil Erosion Research Laboratory, South Russell and Nimitz Dr., Purdue University, West Lafayette, IN 47907 (317) 494-8685. ♦

Process May Sweeten Sugarbeet Profits

Sugarbeet processors might be able to squeeze more profits out of every sugarbeet that comes into their factories by using a process modified and tested by ARS researchers in California.

Sugarbeets that are exposed to lime, heated, then squeezed in three successive runs through powerful presses will yield an estimated 10 to 20 percent more pulp than beets processed with the conventional diffusion method, says chemical engineer John M. Randall.

He says that boost in pulp yield could mean 25 to 50 more tons of dry pulp per operating day for a factory processing 5,000 tons of beets each day.

Randall, recently retired from ARS' Western Regional Research Center, Albany, California, worked on the beets with colleagues Richard H. Edwards and Wayne M. Camirand of the Albany laboratory.

Sugarbeet pulp, once its sugar juice is squeezed out of it, is dried in huge dryers, then either shaped into pellets that are sold as an ingredient in dairy cattle feed, or ground into a powdered, high-fiber additive for foods we eat. Sugar juice is purified, then evaporated to form the familiar crystals.

Perhaps even more important than the anticipated boost in pulp yields, beet processors can expect a 10 percent or higher savings in energy costs by using the liming-and-pressing process. The approach produces tougher pulp that requires less energy to dry. In an industry where up to 25 percent of the total required to process sugarbeets goes into drying out pressed pulp, energy savings from the new process could be important, says Randall. Right now, European processors have shown more interest than Americans in the method.

With the technique, sugarbeets that have been freshly sliced into narrow, sticklike "cossettes" are dipped in a lime (calcium hydroxide) slurry or dusted with powdered lime, then heated. In the pressings that follow, water is added only once, as compared with the diffusion process, in which the cossettes are bathed in hot water to extract their sugar.

Laboratory experiments indicate juice from the limed cossettes should yield about the same amount of sugar as conventionally processed beets.

Randall estimates an average factory would need to invest at least \$1.5 to 2.2 million in new equipment for the liming approach. But a strong market for pulp combined with the expected energy savings could make that investment pay off, he says.

Although the idea of using lime in sugarbeet processing dates back to at least 1905, Randall is probably the first to so extensively test the liming and pressing combination.—By **Marcia Wood**, ARS.

Richard H. Edwards and Wayne M. Camirand are at the USDA-ARS Western Regional Research Center, 800 Buchanan Street, Albany, CA 94710 (415) 559-5852. ♦

Shade Umbrella Stops Weeds

Soybean plants maturing in a greenhouse in west-central Minnesota may lead to a new variety that will outcompete weeds in the northern United States.

Frank Forcella, formerly an agronomist for the Agricultural Research Service in Morris, Minnesota, hopes that at least some of the new plants will cut herbicide use by 75 percent.

That's the percent reduction Forcella has seen with a Midwestern soybean variety. The reduction comes from a superior leafing ability. The leaves, once produced by the plant, grow bigger faster.

"It's extremely important for soybeans to have as much leaf area as possible during the first 50 days of growth," Forcella says. With a big enough crop umbrella, weed seedlings receive insufficient sunlight for normal growth.

DON BRENEMAN

ARS technician Dean Peterson at Morris, Minnesota, compares growth of hybrid soybean plants with improved leaf area (right) with a normal variety on left. The hybrids are also competing with foxtail and pigweed in this test. (88BW2244-22)

Having seen what genes for superior leafing in a Midwestern variety could do to weeds, Forcella set out to breed a similar soybean that would mature more quickly to avoid the northern frost.

The seeds planted this past November came from five promising lines selected from thousands of progeny from the crosses.

"These plants have high leafing ability—25 to 50 percent better than their parents—as well as a short maturity and a reasonably good yield," says Forcella. "Yield was not our prime target at this stage. We don't know if these seeds will develop into plants that greatly reduce herbicide use as the Midwestern variety did, but that's what we're working toward.

Dean Peterson, ARS research technician at Morris, is evaluating greenhouse data and planning to field-test promising plants this spring.—By **Don Comis**, ARS.

Frank Forcella, formerly with the USDA-ARS North Central Soil Conservation Research Laboratory, Morris, MN 56267 (612) 589-3411, is now at the University of California, Davis, 95616 (916) 752-4178. ♦

Shortcut for Bluetongue Research

In searching for vaccines against insect-spread viral disease, scientists are often hampered by a lack of test animals or it may be the wrong time of year for insect carriers of the virus. Rearing insects in the laboratory is usually difficult and expensive.

Now an Agricultural Research Service veterinary medical officer has found a shortcut for studying one such insect-carried disease—bluetongue.

Although most ruminant animals are susceptible to bluetongue, it's a mild disease for most species; only sheep are badly stricken by the symptoms, which include mouth sores, a discolored tongue, lameness, and abortion.

The virus' presence in U.S. cattle and sheep has resulted in international barriers to our exports, perhaps costing as much as $125 million in lost cattle sales each year.

ARS' Sally J. Wechsler and coworkers at the Arthropod-borne Animal Diseases Research Laboratory, Laramie, Wyoming, were the first to develop a cell line from *Culicoides variipennis*—the biting midge that carries bluetongue virus among animals in North America. Cell lines are collections of cells that reproduce in laboratory containers.

"The biggest challenge in developing a cell line is finding cells that replicate themselves and thrive in the liquid diet we feed them. We discovered cells from 2-day old insect embryos grew well in a liquid mixture that other scientists use for studying cells of the fruit fly," says Wechsler.

Bluetongue virus, as well as epizootic hemorrhagic disease virus, the cause of another potentially costly disease, reproduce well in this cell line over a wide range of temperatures—roughly 65°F to 100°F.

The cell line may speed research because it is easier to use for some experiments than the whole insects that the laboratory mass rears for other studies.

For example, Wechsler says she will design experiments to learn what these insect cells have in common with cattle and sheep cells. Viruses transmitted by insects must attach themselves to cells at receptor sites.

This is basic research, she says, that might lead to a vaccine. Once receptor sites are identified, researchers might try to alter the bluetongue virus into a harmless form that grabs onto the same sites. Hopefully, this will cause animals to build immunity to the virulent forms without causing disease.—By **Dennis Senft,** ARS.

Sally J. Wechsler is at the USDA-ARS Arthropod-borne Animal Diseases Research Laboratory, P.O. Box 3965, University Station, Laramie, WY 82071-3965 (307) 721-0316. ♦

Patents

Bacteria Zap Wheat Weeds

Weeds like downy brome, growing in the midst of winter wheat and other cereal grains, may soon be biologically controlled.

These weeds, which cost growers at least $375 million a year, cut winter wheat yields up to 45 percent by competing with crops for moisture, space, and nutrients. They've been spreading in recent years because conservation tillage systems, in which straw and other residues from the previous year's crops are left on the soil surface to slow erosion, make these weeds more difficult to control than with conventional tillage systems, where residues are plowed under.

ARS scientists found that certain strains of naturally occurring soil bacteria, in the genus *Pseudomonas,* can selectively kill or slow the growth of downy brome (also known as cheatgrass) and other weedy grasses in wheat, barley, oats, rye, and triticale.

"Since we do not have a herbicide for downy brome in wheat, this biocontrol method comes at the right time," says microbiologist Lloyd F. Elliott, who until recently was located at ARS' Land Management and Water Conservation unit in Pullman, Washington.

This may be the first time scientists have devised a way to get microorganisms to grow in the field and inhibit only the roots of weeds.

According to Elliott's coworker at Pullman, soil microbiologist Ann C. Kennedy, these bacteria are most effective in late fall and early spring when temperatures are low. By reducing the growth of downy brome roots early in the growing season, the bacteria allow the cereal crop to compete more effectively, thus reducing the negative impact of the weed on crop yield.

The pseudomonads are sprayed on the soil surface or residues where they begin to multiply and colonize the growing roots of downy brome.

"Once in the root zone, the pseudomonad bacteria produce toxins that interfere with the weeds' growth, often killing them," says Kennedy. "Those weeds that survive the winter may die or be so weakened they can't compete with the grain crop."

She says spraying the soil surface with pseudomonads before planting can boost yields of winter wheat as much as 35 percent.

Early test results indicate a single application of the bacterium can eliminate over 50 percent of the weeds, says Kennedy, but actual control will have to be verified in future field tests.

More than 2 years of field tests will be run to ensure the bacterium suppresses only the weeds. If it does, farmers may get the green light to apply these environmentally safe bacteria to their fields.—By **Howard Sherman,** ARS.

For technical information, contact Ann C. Kennedy, USDA-ARS Land Management and Water Conservation, Room 215, Johnson Hall, Washington State University, Pullman, WA 99164-6421 (509) 335-1552. Patent Application Serial No. 07,207,592, "Method for Screening Bacteria and Application Thereof for Field Control of the Weed Downy Brome." ♦

Letters

On Vitamin E and Immunity: *[Dr. Meydani comments about a January 17, 1989 Washington Post story, Eating Right.]*

I am writing to clarify any misconceptions that might arise from the article on vitamin E and immunity and vitamin E supplementation in the elderly. While the result of this carefully designed and controlled study indicates that certain factors in immune response are enhanced by vitamin E, it is by no means a prescription for everyone to consume megadose supplements of vitamin E.

The study was conducted over a short period—30 days—and we do not know whether the positive effects will also continue with extended supplementation. We have only tested with 800 I.U. of supplementation.

While we did not observe any signs of toxicity at 800 I.U., neither was this the focus of the study. We studied immune function through a variety of tests but did not examine the incidence of disease, so no claims of therapeutic efficacy or protection can be made.

As provocative as the results of our study are, before further research is completed it would be premature to use them as the basis for recommending vitamin E supplements for older individuals.

Simin Nikbin Meydani
Tufts University, Boston

On Africanized Bees: I am sure that I am the hundreth person to write to you to point out an error in the January [1989] issue of Agricultural Research magazine. The error occurs on page 4 in the drawing of the bee in the upper left hand corner. As an amateur apiculturist with 36 years experience rearing honey bees, I can say with certainty that the bee carrying the suitcase is dead. Any beekeeper would recognize this from the fact that the leg from which the suitcase is suspended is hanging down. Thus, it would be impossible for the bee to be in flight. Otherwise, I found the articles on bees to be most interesting.

J.R. Johnson
Schaumburg, Illinois

It's hard to get them to pose alive.— ***Ed.***

On Selenium: I just read your "How Reliable are the Numbers?" [January 1989] and completely agree with you that some sort of standardization of tests and figures needs to be established.

Obviously, things had to be condensed considerably to fit the space but I am a bit concerned about your example of selenium levels in beef being "reported as low as 5 and as high as 40 micrograms per 100 grams." These figures are both likely to have been correct as reported. . .[if tests for selenium content were made on different animals that had eaten feed from different parts of the United States.]

Mrs. LeRoy H. Reiber
Twisp, Washington

The example was meant—though not clearly worded—to show the kind of differences in data that the ARS computer program, SELEX, could address with a reliability rating.— ***Ed.***

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